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ABSTRACT

This study explored how, and what type of, procedural instructions influence a trade-off between planning and performance. There is a trade-off if longer planning time shortens performance time, improves performance efficiency, and improves accuracy. The relative effectiveness of nine combinations of illustrated and written instructions for an assembly task were compared. Three time measures were used: (1) total session time; (2) planning time; and (3) performance time. Other performance measures were efficiency and accuracy. It was concluded that there was a trade-off between combined instructions versus totally illustrated or totally written instructions. The degree of operational information in totally illustrated or totally written instructions also influenced planning and performance, but in different ways. Accuracy was less affected by the instructional variations than by other comprehensive measures because sufficient clues appeared in the core information of all instructional variations. (JD)

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The Planning Performance Trade-Off in Use of Textual and Illustrated Procedural Instructions

by

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Running Head: PROCEDURAL INSTRUCTIONS SYMPOSIUM

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ABSTRACT

The purpose of this study was to explore how and what type of procedural instructions influence a trade-off between planning and performance. There is a trade-off if longer planning time shortens performance time, improves performance efficiency and improves accuracy. The trade-off effect was considered an indicator of instructions that are effective and that facilitate the acquisition of proceduralized knowledge. Good instructions should assist the learner to pass through the stages of skill acquisition more quickly to achieve proceduralization.

The trade-off between planning and performance was addressed by comparing the relative effectiveness of nine combinations of illustrated and written instructions for an assembly task. Within illustrated and written instructions, the operational information was varied, although the statistical design contrasted instructional formats. The study involved three time measures: total session time, planning time, and performance time. Other performance measures were efficiency and accuracy.

Results of the analyses (i.e., five one-way ANOVAs and post-hoc analyses) provided partial support for the prediction that a trade-off occurred for combined instructions vs totally illustrated or totally written instructions. All

groups given combined instructions had equal session times, were more efficient than groups given illustrations lacking operational information, and were somewhat more accurate than certain other groups.

It was concluded that there was a trade-off between combined instructions vs totally illustrated or totally written instructions. Also, operational information had to appear in at least one format (i.e., illustrated or written). The degree of operational information in totally illustrated or totally written instructions also influenced planning and performance, but in different ways. Finally, accuracy was less affected by the instructional variations than other comprehension measures because sufficient clues appeared in the core information of all instructional variations.

Planning is one aspect of any problem-solving task (Konoske, 1984), and this study supported the notion that planning of even simple, but unfamiliar procedures improves ultimate performance. From the perspective of Anderson's (1982) three-stage theory of skill acquisition, the findings suggested that combined instructions promote greater planning time, without putting as great a strain on working memory as totally written instructions, and without sacrificing accuracy. Practical implications for the design of procedural instructions were presented.

INTRODUCTION

Background: Although immensely practical and importance, little is known about the processing of procedural instructions and factors that contribute to successful procedural execution. Procedural instructions consist of an ordered sequence of steps or operations performed on a single object or under specific situations. Examples of procedural instructions include recipes, operating instructions, navigation directions, management procedures and procedures for assembly, repair or troubleshooting of equipment. Printed procedural instructions appear in illustrated, written or combined formats. Procedural instructions are associated with functional literacy; they are "read to do" (Smillie, 1885, as cited in O'Donnell, et al., 1987) and not to just verbally comprehend. Functional literacy is demonstrated when a person reads a set of procedural instructions and successfully performs the actions described in the instructions. Functional reading differs from general literacy in the nature of the users' unobserved cognitive activities, their observed activities, and in the texts associated with the development of this special form of literacy.

People in all walks of life encounter tasks requiring the use of procedural instructions. However, the instructions are not always effective. For example, some consumers prefer to ignore procedural instructions because the information is perceived as inaccurate, incomprehensible or unnecessary (Wright,1981). Other people avoid careful reading but skim instructions for specific details, and consequently, encounter difficulties. Studies show that the utility of manufacturers' operating instructions improves when they are rewritten (Charney & Reder, 1986; Sremec, 1972; Kieras, 1985). In the military, which conducts extensive functional literacy training, problems have been noted with maintenance manuals because they are hard to use, outdated, or inaccurate (GAO, 1979, cited in Stone & Crandell, 1982) or present material in a manner that inhibits retention (Konoske, 1985). These situations point out the real need to research how people use and follow procedural instructions.

Much research exists about general literacy involving comprehension of narrative or expository text (See for example, Britton & Black, 1985; Kieras, 1980, 1981; Rummelhart & Ortony,1977; Schallert, 1982; Thorndike, et al., 1980) but procedural text has virtually been ignored by instructional technology, prose analysis and cognitive psychology. Similarly, the value of illustrations as procedural instruc-

tions or as adjuncts to procedural text has had relatively little study.

Few studies of procedural instructions have involved actual enactment of target tasks. However, a series of studies of object assembly suggested that combined text and illustrations are generally better than text or illustrations alone (Bieger, 1982; Crandell, 1979; Martinez-Boyd, 1987; Schorr, 1983; Stone,1977). Text improved performance accuracy and efficiency of moves while illustrations hastened encoding (i.e., shortened reading time) and assembly speed (Martinez-Boyd, 1987). Martinez-Boyd (1987) found that the presence of combined instructions was one of several predictors for assembly time and accuracy, but the presence of text predicted assembly efficiency (i.e., number of moves the subject used when building). Martinez-Boyd (1987) also concluded that combined illustrated and textual instructions accomodated individual differences among users (i.e., gender, cognitive style, reading memory, and related experience). These same combined instructions minimized the user's need to problem-solve or troubleshoot as long as the instructions were explicit. Other related studies found that the placement of text relative to illustrations was not important; and, the redundancy between text and illustrations was also not important (Ausel, 1984; Bieger, 1982).

Functional explanations in the text and hierarchically ordered information were sometimes helpful (Smith & Goodman, 1984; Konoske, 1985) but were not always needed (Martinez-Boyd, 1987). Smith & Goodman (1984) compared written instructions which did or did not contain hierarchically arranged, explanatory (i.e., how-it-works) information. They found that the text which contained explanatory information was longer but was read faster than the shorter, step-by-step, linear instructions. Explanatory text facilitated transfer of learning to a new, but similar task. The original task was assembly of an electric circuit configuration for lighting a light bulb.

Konoske (1985) varied the text in her toy assembly study and similarly found better performance when instructions were hierarchically organized rather than linear. In both studies (Smith & Goodman, 1984; Konoske, 1985), the texts were complemented by a single diagram, but the influence of it was not assessed. Subjects were given verbal recall tests and were asked to assemble objects from memory.

In a study contrasting nine combinations of textual and illustrated instructions for toy assembly, Martinez-Boyd (1987) compared the overall effectiveness of hierarchically arranged illustrations or text over less detailed, linear illustrations or text. No significant differences were found

when groups were compared on assembly time, efficiency, and accuracy. Unlike the prior studies (Konoske,1985; Smith & Goodman, 1984), her study did not test recall of instructions or transfer of learning. Also, subjects were allowed to refer to the instructions while building.

Enactment of procedural instructions involves skill acquisition, which according to Anderson (1982), is a three stage process. Declarative knowledge results from the first stage and is gained from text. The user receives instructions and information about the procedure which become encoded as a set of facts or steps mediated by verbal rehearsal, subvocalizations, drill and practice, or other elaborative techniques. Activities such as oral summarization, mental imagery, elaboration, and cooperative learning have been shown to facilitate the acquisition of declarative knowledge and promote the declarative stage (See O'Donnell et al., 1987). The declarative stage similarly arises in general literacy and functional literacy tasks and involves formulation of an initial characterization of information in the text.

The facts extracted from procedural text are rehearsed in working memory to keep them available for interpretation while enacting the procedures. The limits of working memory and its ability to handle large amounts of information, if

meaningfully "chunked", have been described extensively in the literature (See, for example, Daneman & Carpenter, 1980, 1983; Kieras & Polson, 1982). Through practice, the novice user is able to directly convert declarative knowledge into procedures without the intercession of rehearsal or elaboration. The general framework which converts declarative knowledge to procedural knowledge is a process called knowledge compilation (Anderson, 1982).

The three stages of skill acquisition proposed by Anderson (1982) are: (1) declarative stage, (2) knowledge compilation stage, and (3) proceduralization stage. One indication that skill acquisition occurs in stages is that comprehension (i.e., recall or enactment) differs depending on what stage is being stressed (O'Donnell, et al., 1987; Stone & Crandell, 1982).

The current experiment focused on the second stage, the knowledge compilation stage. This stage was selected for study because of its impact on proceduralization for even the simplest skill. The skill in the present experiment was assembly of a toy. The user of the instructions was assumed to pass through the declarative stage but this was not measured directly (the goal of the task was not recall of the instructions). Looking back at the instructions while building was allowed (this is commonly done by consumers

while assembling). Anderson (1982) promotes looking back, or prompting, to enhance comprehension of detailed instructions and to minimize the load on working memory. In the current study, the subjects' working memory was engaged while they enacted the instructions without reading them.

Processing and executing procedural instructions are forms of problem-solving. In object assembly, tasks can differ in terms of : (1) amount of planning or preparation, (2) number of steps and sub-tasks, (3) amount of cuing built into the task, (4) number of decision points, (5) whether order of steps can vary and to what degree, and, (6) whether the goal of the task is assembly, operation or troubleshooting (Konoske, 1985). The present experiment addressed the issue of planning vs performance as it is influenced by the amount and organization of operational information in textual or illustrated procedural instructions. The task did not vary.

Research Problem: There are inconclusive research findings concerning the utility of instructions that encourage more planning or preparation before enacting procedures. In an object assembly task where written and illustrated instructions were used, the subjects' naturally occurring planning behaviors inconsistently varied with type instructions

(Schorr, 1983). Three related studies (Ausel,1984; Bieger, 1982; Stone,1977) found that having redundant information in text and illustrations did not necessarily improve toy assembly but did increase the time spent reading the instructions (i.e., one measure of planning time).

Bieger (1982) specifically found that there were four essential semantic concepts that had to appear in textual or illustrated procedural instructions. These were contextual, spatial, inventory and operational information. Assembly speed or accuracy were influenced by whether the information appeared in text or illustrations. For example, Bieger (1982) found that with spatial information, there was a trade-off between making more errors or taking more time. When spatial information was presented in the text, there were fewer errors but the task took longer to complete. When spatial information appeared in illustrations, there were more errors but the task was completed quicker. It is possible that certain instructions promote better planning than others.

O'Donnell and her associates (1987) found that planning, when taught as a cooperative learning strategy, helped paired students encode unfamiliar medical procedures declaratively as compared to three other cooperative learning strategies (i.e., none, baseline, prompting). When tested, the

planning group wrote the best summaries of the procedure. While training, these subjects were directed to plan the medical procedure aloud before performing it; each subject in the pair alternated performing each of the steps in the procedure. However, subjects who referred to their instructions or conferred with their partners during the training period (prompting group), and did not plan aloud, performed the procedure better than the three other groups during the testing period. It is interesting to note that all four groups in the O'Donnell et al. (1987) study did not differ in their total session time, but did differ in the amount of time spent in preparing to perform vs performing.

Rationale for This Study: Reviewed together, the findings from these studies (Ausel, 1984; Bieger,1982; O'Donnell, et al., 1987; Schorr, 1983; Stone, 1977) suggest that there may be a trade-off between planning and performance in time taken to enact procedures. Generally speaking, a trade-off occurs if longer planning time shortens performance time and improves accuracy but does not affect total time (i.e., planning and performance time combined). Good procedural instructions should provide this trade-off. By contrast, one definition of less effective instructions would be instructions that promote lengthened planning time (e.g.,

take an extraordinarily long time to read and understand) or performance time (e.g., provide so little information that the user is forced to resort to trial-and-error performance). As a consequence, the poorer instructions affect total time, which results in no trade-off effect.

The purpose of the current experiment was to explore how and what type of procedural instructions influence the trade-off between planning and performance. If better planning shortens performance, then the stages of skill acquisition can be passed quicker to achieve proceduralization. A trade-off occurs if the total session time is not affected. Proceduralized knowledge is one important outcome of functional literacy. The trade-off effect is considered an indicator of instructions that are effective and that facilitate the acquisition of proceduralized knowledge.

The trade-off effect was addressed in the current study by comparing the relative effectiveness of nine combinations of illustrated and written instructions. The criteria for designing the instructions came from a review of research in educational technology, prose analysis and cognitive psychology. The instructions varied the format (none, illustrated or written) and degree of enhancements. These enhancements and formats varied the operational (i.e., how-to) information in procedural instructions. Operational information is one

critical component of procedural instructions (Bieger, 1982). A no-instructions group (i.e., control) was used to verify that the task required instructions at all.

The current study involved three time measures: total session time, planning time, and performance time. Total session time was the total time spent planning and performing the assembly task. Planning was measured by time spent initially reading the instructions combined with time spent looking back at the instructions after commencing assembly. Performance was measured by time spent manipulating the assembly pieces without looking at the instructions. Performance also included measures of efficiency (number of moves), and accuracy (accuracy score).

Because prior research (Bieger, 1982; Crandell, 1979; Martinez-Boyd, 1987; Schorr, 1983; Stone, 1977) suggested that learners of an object assembly task learn best when given combined written and illustrated instructions, the present study's prediction was that the trade-off would occur for combined instructions when compared to totally written or totally illustrated instructions. A trade-off was defined to occur if increasing planning time resulted in: (1) decreased performance time,(2) improved efficiency, and (3) improved accuracy.

The enhanced textual instructions included hierarchically arranged, explanatory information about how each subassembly of the toy should operate and how it related to the overall assembly. The enhanced illustrated instructions included a series of hierarchically arranged sub-assembly illustrations. The series showed how each sub-assembly should be built. Prior sub-assemblies were referenced in each illustration. Some research suggested that these enhancements make step-by-step procedural instructions more understandable to the learner (Bieger, 1982; Bromage & Mayer, 1981; Crandell, 1979; Konoske,1985; Smith & Goodman,1984), although there is some doubt that this is true in all cases (Martinez-Boyd, 1987).

Therefore, the predicted outcome of the present study was that the trade-off effect would occur when the learner received text and illustrations. This effect would not occur when the learner received totally textual or totally illustrated instructions.

Predictions: Combined text and illustrations were expected to generally be better than text or illustrations alone. However, a prior study found that text improved performance accuracy and efficiency, while illustrations hastened planning time (Martinez-Boyd, 1987). Therefore, the trade-

off effect between combined instructions, on the one hand, and totally written or totally illustrated instructions, on the other hand, needed to be specified. The trade-off is described in the predictions stated here.

(1) Total Session Time: Groups given combined instructions would have different total session times than groups given totally illustrated or totally written instructions.

(2) Planning Time: Groups given combined instructions would have different planning times than groups given totally illustrated or totally written instructions.

(a) Groups given combined instructions would plan longer than groups given totally illustrated instructions.

(b) Groups given combined instructions would plan less time than groups given totally written instructions.

(3) Performance Time: Groups given combined instructions would have different performance times than groups given totally illustrated or totally written instructions.

(a) Groups given combined instructions would perform less time than groups given totally illustrated instructions.

(b) Groups given combined instructions would perform more time than groups given totally written instructions.

(4) Performance Efficiency: Groups given combined instructions would require a different number of moves to build the toy than groups given totally illustrated instructions.

(a) Groups given combined instructions would build the toy in less moves than groups given totally illustrated instructions.

(b) Groups given combined instructions would build the toy in approximately the same number of moves as groups given totally written instructions.

(5) Performance Accuracy: Groups given combined instructions would differ in their accuracy when compared to groups given totally illustrated or totally written instructions.

(a) Groups given combined instructions would be more accurate than groups given totally illustrated instructions.

(b) Groups given combined instructions would be more accurate than groups given totally written instructions.

METHOD

Participants: One hundred and eight undergraduates, aged 18 to 24, completed the experiment. Of the 108 participants, 90 (83%) were from a Maryland State College and the remainder were enrolled in two private colleges in Maryland. There were 54 males and 54 females. Participants were randomly assigned to one of nine instructional groups after being blocked according to gender (n=12 per group).

Materials: The necessary materials were as follows:

(1) Nine different booklets of instructions and associated orientation information for the subject and experimenter to use (See next section, "Instructions");

(2) "Needed Parts List", which gave a drawing and technical name for each of ten different pieces (It was included in the booklet of instructions);

(3) Twenty-six pieces from the Fischer-Technik 100 © in a covered box;

(4) Assembly Scoring Sheet to record assembly speed, efficiency and accuracy;

(5) Pencils, pens, and felt markers;

(6) Small note pad to display subject identification number in front of video camera; and,

(7) Videotape cassettes to record subject planning and performance behaviors.

The Fischer Technik kit 100 ® was used as the stimulus material because the kit is relatively unfamiliar in America. Many researchers of procedural instructions used this same kit (Ausel, 1984; Baggett, 1983, 1984; Baggett, et al., 1982, 1985; Bieger, 1982; Crandell, 1979; Holland, et al., 1985; Martinez-Boyd, 1987; Schorr, 1983; Stone, 1977). The kit contains 72 different abstract pieces and can be used to build countless objects; one of these objects is the 14-piece, five sub-assembly go-cart described in this study. The assembled go-cart was approximately 5 1/2" long, 2 1/2" wide and 2 1/2 " high. The toy could be built with a minimum of 34 steps. Relatively limited and discrete motor skills were required by the subject (Schmidt, 1975), so that the effect of manual dexterity was minimal as compared to continuous motion assembly tasks, like knot-tying (Holland, et al., 1985).

The 26 stimulus pieces included 14 which were needed and 12 extras. The extra parts were either: (1) the same as the needed parts (e.g., extra go-cart wheels, extra back axles); (2) parts that resembled the needed part but did not function properly (e.g., a grey rod with no square end could not serve

as a steering column although the correct rod with a square end could); (3) parts that did not resemble the needed part but could function in its place (e.g., a small gear could incorrectly serve as a steering wheel rim).

Instructions: Nine different booklets of instructions were used. The instructions varied the operational (i.e., how-to) information within each instructional format (none, illustrated or textual). The characteristics common in the nine instructions were the: (1) stated goal of the task; (2) quantity, illustration, and name of the needed parts; (3) the method of evaluating whether the assembled go-cart operated properly; and, (4) the method of informing the experimenter of task completion. The nine instructional groups are described in this section of the study report and in Table 1. Figures 1 through 4 are excerpts from the instructions.

(1) No Illustrations, No Text (No Illust/No Text): This group had the least amount of information for building the go-cart. These subjects were given the four minimal pieces of information described earlier. Steps for building the go-cart (i.e., how-to information) were not given.

(2) Minimal Illustration, No Text (Min Illust/No Text): This group received what group one received, and also got an exploded diagram. An exploded diagram is a scaled, three-

dimensional drawing of a disassembled device that shows the device's major components (subassemblies) and subassembly pieces in alignment. Exploded diagrams are typically used in assembly tasks. In this experiment, the exploded diagram preceded the short written goal statement.

The subject was expected to look at the drawing, interpret the subassemblies him/herself and understand where or how to insert the pieces. The exploded diagram did not indicate in what order to build the go-cart or how the fully assembled go-cart should look.

(3) Enhanced Illustrations, No Text (Enhanc Illust/ No Text): This group received what group one received plus a series of five explicit sub-assembly illustrations. The series depicted how the sub-assembly should be built, and showed this from the same angle as the exploded diagram. These instructions were hierarchically arranged because previously built sub-assemblies were referenced by dotted lines. Arrows and enhanced details described how the particular sub-assembly should be built. Components of the sub-assembly were shown in fully and partially aligned positions.

The subject was expected to look at the drawing to interpret where and how to insert the component. The subject was also expected to look at the drawing to see what

the go-cart sub-assembly should look like once the components were inserted. Each sub-assembly appeared on a separate page.

(4) No Illustration, Minimal Text (No Illust/Min Text): This group received what group one got but also received linear textual instructions. The linear text was minimal because it gave step-by-step directions for building the go-cart without dividing the task into sub-assemblies. The text did not provide a rationale for each step and did not describe how each sub-assembly operated or how it related to the overall assembly. Linear text typifies assembly instructions encountered by consumers.

The subject was expected to read the text, interpret the sub-assemblies him/herself and understand where and how to insert the components. The directions for each sub-assembly appeared on separate pages.

(5) Minimal Illustration, Minimal Text (Min Illust/Min Text): This group received a combination of group two and group four instructions. The minimal instructions, an exploded diagram, appeared before the step-by-step, linear text.

The subject was expected to review the exploded diagram in conjunction with the linear text. Sub-assemblies were not specifically described. Text described how, and in what

order to, insert components whereas the exploded diagram clarified where to insert them.

(6) Enhanced Illustrations, Minimal Text (Enhanc Illust/Min Text): This group received a combination of group three and group four instructions. Each explicit sub-assembly illustration preceded the related text.

The subject was expected to review each sub-assembly illustration and text together. Sub-assemblies were depicted in the illustrations but were not described in the text. The text described the steps for building the go-cart.

(7) No Illustrations, Enhanced Text (No Illust/ Enhanc Text): This group received what group one received plus hierarchical, explanatory text. Hierarchical, explanatory text included everything in the linear text plus more. That is, the hierarchical explanatory text described the compo-nents to use and the order in which to assemble each sub-assembly but also gave explanations. Explanatory text provided a rationale for each step based on a simple repre-sentation about how the sub-assembly operated and how it related to the overall assembly. See the "Functional Concept of the Go-cart".

The subject was expected to understand how pieces fit together and why it was important to attach them in certain

ways. However, there were no sub-assembly drawings to use as a check of proper execution of steps described in the text.

(8) Minimal Illustration, Enhanced text (Min Illust/ Enhanc Text): This group received a combination of group two and seven instructions. The exploded diagram preceded the entire text. The subject was expected to review the diagram and text together. The text described sub-assemblies whereas the exploded diagram did not include sub-assemblies. The exploded diagram did not show how the fully assembled go-cart should look. The text described how pieces fit together and why. The exploded diagram could be used as a check for where and how to insert pieces but could not be used to check order of assembly.

(9) Enhanced Illustrations, Enhanced Text (Enhanc Illust/Enhanc Text): This group received the most information available for assembling the go-cart. They got a combination of instructions given to groups three and seven. Each explicit sub-assembly illustration preceded the related text. The operational information was redundant in the illustrations and text.

The subject was expected to review each sub-assembly illustration and text together. Sub-assemblies were depicted in the illustrations and described in the text. The text described how the pieces went together and why.

Development of the Instructions: The drawings were made in a similar manner to those of Schorr (1983) and Crandell (1979); but, slightly different explicit drawings were done so the user could see details needed for assembly. All the illustrations were modifications of the drawing in Holland et al.'s (1985) study. The basic text came from the best writer in Holland et al.'s (1985) study. However, the text was modified in accordance with Baggett's (1983) guidelines and the purpose of this study. The textual and illustrated instructions were also developed in accordance with guidelines suggested by educational technologists and prior research (Felker, 1980; Felker, et al., 1981; Hartley & Burnhill, 1977; Mayer, 1976; Szlichcinski, 1979; Wright, 1977, 1982). All versions of text included four essential components of procedural instructions identified in manuals for technical writers (Houp & Pearsall, 1984).

Analysis of the Illustrations and Texts: Pine & Bieger (1980) have contended that studies which examine the effect of illustrations as an interpretive aid to text have been flawed because researchers did not provide a precise description of the semantic content of both instructional formats. To overcome this methodological flaw, analyses were

performed of all illustrations and text used in the current study.

The analysis (see Martinez-Boyd, 1987) of the semantic content substantiated that enhanced instructions provided more information than minimal instructions. The analysis showed that the enhanced text was longer as measured by number of: words, sentences, paragraphs and propositions. Enhanced text had more hierarchical goal statements, and provided more categories of information than minimal text. Although enhanced text had more information, it contained a smaller proportion of high density sentences and was rated as grade 7 readability versus grade 9, for minimal text (Fry measure, as cited by Staff,1977). All but four of the words in the text rated at grade 7 or lower (IOX, 1980). The explicit sub-assembly illustrations provided more categories of information than the minimal illustration or parts list.

Functional Concept of the Go-Cart: The functional concept of the go-cart was included as information in all versions of the instructions that had enhanced text. The concept was as follows.

" The go-cart has five sub-assemblies; these are the chassis, the front axle, the steering assembly, the rear axle and the towing piece. If properly assembled, the go-cart can

be pushed or pulled in a forward or backward direction and steered to go right, left or straight.

The go-cart can turn or go straight because the front axle, which supports the front wheels, is controlled with the steering assembly. The steering assembly is directly connected to the front axle through the steering column. The steering column is held in place with a C-clamp. If the C-clamp is not properly secured, the steering column will slip, which can cause lost control of the front axle. Then, the go-cart will not move in the desired direction. The rear axle is fixed. The rear wheels follow the front wheels in a straight-line motion. The towing piece is attached to the rear of the go-cart. It has no moving parts."

Equipment: VCR equipment was used to videotape planning and performance behavior and to analyze subjects' behavior.

Procedure: The procedure was piloted with 15 people before study data were collected. Two experimenters ran the official experimental sessions although most of the data were collected by the author. The experiment took approximately 30 minutes per subject and each subject was seen individually by an experimenter. All 108 subjects successfully completed the task although two females did not build a totally

functional go-cart. All subjects were encouraged to keep working until they could achieve this goal, or until they could work no more (i.e., were fatigued).

Subjects were told to first review the entire set of instructions one time before assembling. The subjects were told to assemble quickly and accurately. They could refer to the instructions while building as needed. The printed instructions given to all subjects described how to check the operation of the completed go-cart. All instructions also indicated that subjects had to ring a bell when they had completed the task.

During the experimental session, equipment and materials were arranged in a standard configuration. The entire experimental session was videotaped for each subject.

Scoring of Planning and Performance: Planning was analyzed using the amount of time spent initially reading the instructions and looking back at them after commencing assembly. Performance was based on assembly time, assembly efficiency (number of moves) and accuracy. Working memory was assumed to be primarily engaged while the subject assembled. A trade-off between planning and performance occurred if longer planning time shortened performance time and improved

assembly efficiency and accuracy. The trade-off did not lengthen the total session time.

(1) Planning time: (a) Initial reading time: Number of seconds spent reviewing the booklet of instructions before being able to see the assembly pieces. (b) Look-back time: Number of seconds spent looking back at the booklet of instructions after having seen the assembly pieces but before completing the task.

Planning time did not distinguish what in the instruction booklet was being reviewed (e.g., text or illustrations in combined instructions).

(2) Performance time: Assembly time: Number of seconds spent on the task after the initial reading of instructions was over. Look-back time was excluded from this time measure.

(3) Performance efficiency: Number of moves: A move was any discrete action involving the subject's hand and an assembly piece or the partially or fully assembled go-cart. A minimum of 34 moves were needed to build the toy. Moves included actions described by the following examples: touch, lift, put down, connect, screw, snap on, count, rotate, feel, or "play with". Examples of typical action sequences were: (1) S picked up a piece, rotated it, put it down (3 moves); (2) S picked up a piece, transferred it to the left hand,

picked up the partially assembled go-cart with the right hand, attempted to insert the piece in four different spots in the go-cart, then turned over the go-cart, and put down the piece and the go-cart (10 moves). Simultaneous actions with both hands counted as one move if coordinated but as two moves if independent.

(4) Accuracy of assembly steps and final product: Accuracy Score: The subject had to build a minimally functional go-cart. The go-cart could be assembled in any order but an assembly step had to be done accurately for the subject to get points (maximum of 102 points). Accuracy was measured using a checklist and was defined as executing a step in the correct manner, achieving the right outcome per step and creating a go-cart that worked properly. Points were also awarded for using the correct parts. Corrections made before completion of the final product discounted prior errors. So, if the subject repeated a step, the score was based on the final execution of that step.

(5) Total session time: Planning and performance times, combined

Design: The research design was a series of five omnibus one-way analyses of variance (ANOVAs). The three levels within the factors of illustration and text (none, minimal

and enhanced) were collapsed for the analysis. All analyses were followed by the Tukey-HSD Multiple Range Test. One ANOVA assessed Total Session Time. Two separate ANOVAs assessed components of Total Session Time: (1) Planning Time and (2) Performance Time. The fourth ANOVA assessed assembly efficiency (number of moves). The final, and fifth, ANOVA assessed assembly accuracy. See Table 1 for a description of the design.

RESULTS

Reliability of Dependent Measures: The reliability of scores for accuracy, time and moves was checked by employing a second rater to rescore data from 18 (16.7%) of the 108 subjects previously scored by the experimenter. Data from the same 18 subjects were used to measure the reliability of the three scoring procedures. The 18 subjects included one male and female from each of the nine instructional groups. This data also included subjects rated "early" or "late" to assess whether scores were attributable to learned proficiency in scoring by the experimenter. The results of this analysis indicated that the scoring methods were highly reliable (r= .968 to .999).

Total Session Time: Total session time was the number of seconds spent planning and performing. Table 2 gives the

average session times per group. Table 7 indicates that there were significant differences among the groups (F= 17.19; df= 8,99; p< .05). Post hoc mean comparisons indicated that Group 3 (Enhanc Illust/ No Text) had a shorter session time than Group 7 (No Illust/ Enhanc Text). The respective means were 652.42 and 1140.25 seconds. The average total session time for all subjects was 871.44 seconds. Groups given different combinations of illustrations and text did not differ in total session time.

These findings partially support the prediction that combined instructions create a trade-off effect vs totally written or totally illustrated instructions. The groups with combined instructions (i.e., groups 5, 6, 8 and 9) had equal session times, as predicted. However, not all groups given totally illustrated or totally written instructions (i.e., groups 1, 2, and 4) had significantly longer or shorter session times. Only groups 3 and 7 had shorter and longer session times, respectively.

Planning Time: Planning time was the number of seconds spent reading the instructions before and after commencing assembly. Table 3 gives the average planning times. Table 7 shows that there were significant differences among the groups in planning time (F= 17.43; df= 8,99; P< .0000).

Post hoc analyses showed that groups one (No Illust/ No Text) and two (Min Illust/ No Text) planned less time than all other groups except three (Enhanc Illust/ No Text). Group three planned less time than other groups but approximately equal to groups one, two, and nine. Therefore, groups one through three, given no text, spent approximately the same, short time reviewing the instructions (from 224.92 to 296.33 seconds). Group nine (Enhanc Illust/ Enhanc Text) ranked fourth in short planning time ($\underline{m}$= 480.34). Group seven (No Illust/ Enhanc Text) planned the longest ($\underline{m}$= 707.08), and significantly longer than groups one, two, three and nine. All other groups planned significantly longer than groups one, two, and three. The overall average planning time was 466.49 seconds, as shown on Table 3.

These findings provide some support for the prediction that combined instructions create a trade-off effect when compared to totally written or totally illustrated instructions. Group seven (No Illust/ Enhanc Text) planned excessively long whereas groups given totally illustrated instructions planned shorter times.

It is interesting that the planning times of groups three and nine were equal. Reading a series of enhanced illustrations with (i.e., group nine) and without (i.e., group three) enhanced text took about the same time. The

illustrations may have facilitated encoding of the assembly steps.

Performance Time: Performance time was the number of seconds spent manipulating the assembly parts or go-cart. Table 4 gives the average performance times. Table 7 indicates there were significant group differences in performance time (F= 5.61; df= 8,99; p<.0000). Groups one (No Illust/ No Text) and two (Min Illust/ No Text) performed the longest with average times of 702.17 and 646.17 seconds, respectively. They performed longer than all groups given combined illustrated and textual instructions (i.e., groups five, six, eight and nine). The performance times for groups given combined instructions were statistically equal and ranged from 238.08 to 303.33 seconds. Group one (No Illust/ No Text) also spent significantly more time assembling than group three (Enhanc Illust/ No Text). Group one performed for 702.17 seconds while group three performed for 356.08 seconds. The overall performance time for the entire sample was 404.94 seconds (See Table 4).

These data partially support the predicted findings. Subjects performed longer if they had totally illustrated, or no instructions. They did not perform differently when given totally written instructions vs combined instructions.

Performance Efficiency: Performance efficiency was measured by counting the number of moves made while assembling. A move was any discrete action involving the subject's hand and the partially or fully assembled go-cart. Table 5 gives the average number of moves per group. Table 7 shows that groups differed in efficiency (F= 4.56; df= 8,99; p< .001). Post hoc comparisons indicated that all groups given combined instructions made significantly less moves than group two (Min Illust/ No Text). Group two made 919.58 moves vs groups five, six, eight and nine which ranged from 271.00 to 390.33 moves. Group seven (No Illust/ Enhance Text), with a score of 429.25, also made less moves than group two. In addition, group one (No Illust/ No Text), with a score of 819.67, made more moves than three of the combined instruction groups (i.e., groups six, eight and nine). The overall efficiency score was 493.66 as seen in Table 5. Therefore, it took approximately 493.66 moves to execute the 34-step toy assembly.

These findings partially support the predicted results. Subjects with combined instructions built the toy with fewer moves than one of the illustration-only groups (i.e., group two). The behavior of subjects in combined instructions groups did not differ from the behavior of group three (Enhanc Illust/ No Text); their behavior also did not differ

from the behavior of the text-only groups (i.e., groups 4 and 7), although differences were predicted.

Performance Accuracy: Performance accuracy was based on executing each of the 34 steps in any order and building a functional go-cart. All subjects built functional go-carts except two females whose instructions lacked text. The highest possible accuracy score was 102 although the total sample's average score was 95.32. Table 6 gives the average accuracy scores for the entire sample and each instructional group.

Table 7 gives the results of the ANOVA and indicates that significant differences in accuracy occurred (F= 3.52; df= 8,99; $p< .01$). Post hoc comparisons showed that two of the four groups given combined instructions were more accurate than group one (No Illust/ No Text). Group nine, with doubly enhanced instructions (m= 100.75), and group six (Enhanc Illust/ Min Text, m= 98.00) were more accurate than group one, given no instructions (m= 88.25). Group nine (Enhanc Illust/ Enhanc Text) was also more accurate than group two (Min Illust/ No Text). Group two received an accuracy score of 89.50.

Therefore, users provided with certain combinations of instructions were more accurate than users given no instruc-

tions. If the combined instructions were doubly enhanced (group nine), then subjects were more accurate when compared to subjects given minimally illustrated instructions (group two). These findings provide partial support for the predicted outcome of a trade-off between combined instructions vs totally illustrated instructions.

SUMMARY AND DISCUSSION

Summary: The purpose of this study was to explore how and what type of procedural instructions influence a trade-off between planning and performance. There is a trade-off if longer planning time shortens performance time, improves performance efficiency and improves accuracy. The trade-off effect was considered an indicator of instructions that are effective and that facilitate the acquisition of proceduralized knowledge. Good instructions should assist the learner to pass through the stages of skill acquisition more quickly to achieve proceduralization.

The trade-off between planning and performance was addressed in the current study by comparing the relative effectiveness of nine combinations of illustrated and written instructions for an assembly task. Within illustrated and

written instructions, operational information (i.e., how-to) was varied, although the statistical design contrasted instructional formats. The study involved three time measures: total session time, planning time, and performance time. Total session time was the total time spent planning and performing the assembly task. Planning was measured by time spent initially reading the instructions combined with the time spent looking back at the instructions after commencing assembly. Performance was measured by time spent manipulating the assembly pieces without looking at the instructions. Other performance measures were efficiency (number of moves), and accuracy (accuracy score).

Results of the analyses (i.e., five one-way ANOVAs and post-hoc analyses) provided partial support for the prediction that a trade-off would occur for combined instructions, on the one hand, vs totally illustrated or totally written instructions, on the other hand. All groups given combined instructions had equal session times. All groups with combined instructions were more efficient than groups given illustrations lacking operational information. Two of the four groups given combined instructions were more accurate than the group given no operational information (i.e., no illustrations or text). Of the two, more accurate groups with combined instructions, the group with doubly enhanced

instructions was also more accurate than the group given totally illustrated, minimal instructions.

It was concluded that there was a trade-off between combined instructions vs totally illustrated or totally written instructions. It was also concluded that operational information had to appear in at least one format. Finally, it was concluded that accuracy was less affected by the instructions than time or efficiency.

It is possible that the information common to all groups provided enough information to promote a certain amount of accuracy. That information was: (1) stated goal of the task; (2) quantity, illustration, and name of the needed parts; (3) the method of evaluating whether the assembled go-cart operated properly; and, (4) the method of informing the experimenter of task completion.

The findings were partially supportive of the predictions because the presence of combined instructions was not the only influence in the assembly task. The degree of operational information (i.e., enhancements) in totally illustrated or totally written instructions also influenced time, efficiency and accuracy. Enhancements to text-only and illustrations-only instructions affected planning time differently, but affected efficiency and accuracy the same.

The presence of enhanced operational information in totally written instructions extended users' total session time because they had to plan longer. However, enhancements to totally illustrated instructions shortened the total session time by decreasing the planning time, but did not influence the performance time.

The presence of enhancements in the totally written instructions caused users to make less moves than the group given an illustration lacking operational information. The presence of enhancements in the totally illustrated instructions was associated with an average number of moves, equal to the number made in response to combined instructions.

Groups given doubly enhanced instructions were more accurate than groups given no operational information or an illustration lacking operational information. Thus, having enhancements present in totally illustrated or totally written instructions did not improve user accuracy. Refer to Table 8 for a summary of the study's major findings.

Discussion: The findings in the current study are consistent with prior studies of object assembly which indicated that combined instructions were more effective than totally illustrated or totally written instructions (Bieger, 1982; Crandell, 1979; Martinez-Boyd,1987; Schorr, 1983; Stone,

1977). This study and others suggested that redundant operational information, in illustrations and text, were not needed (Ausel, 1984; Bieger, 1982). The predicted trade-off between combined instructions vs totally illustrated or totally written instructions was partially supported. This trade-off phenomenon was referenced in prior research involving enactment of procedural instructions, but was not studied directly (Ausel, 1984; Bieger, 1982; O'Donnell et al., 1987; Schorr, 1983; Stone, 1977).

Planning is one important aspect of any problem-solving task (Konoske, 1984), and this study supported the notion that planning of simple but unfamiliar procedural tasks improves ultimate performance. From the perspective of Anderson's (1982) three-stage theory of skill acquisition, the findings suggested that combined instructions promote greater planning time, without putting as great a strain on working memory as totally written instructions, and without sacrificing accuracy.

Unlike most studies of text comprehension, the current study focused on the second, knowledge compilation, stage. It would be interesting to discover if combined instructions also promote greater recall of procedures, a comprehension measure associated with stage one of Anderson's (1982) theory. Such a discovery would have important implications

for designing different activities to teach trainers of a procedure, or to teach users of a procedure. (For an example of such a study, see O'Donnell, et al., 1987.) Also, the value of enacting a procedure before or after reading the instructions deserves further study, but has been looked at to some degree (Baggett, 1983,1984; Baggett, et al, 1982, 1985; Holland, et al., 1985). Such research has implications for the development of procedural instructions.

When users of procedural instructions are allowed to "read and familiarize themselves" with instructions, as consumers might naturally do, and as the users were instructed to do in this study, productive planning behavior was "induced" by combined instructions. Print induced "mathemagenic" activities, or learning related processes (Rothkopf, 1982) were associated with the use of combined instructions that contained : (1) the goal of the task ,(2) the quantity, illustration, and name of the needed parts, (3) the step-by-step operational information in text or illustrations, (4) the method of evaluating whether the assembled go-cart operated properly, and (5) the method of informing the experimenter of task completion. Explanatory information was not really needed.

Subjects working individually in the current study behaved in a way similar to the paired subjects in O'Donnell

et al.'s (1987) "prompting group". Perhaps when a reader works alone, and has no prompts other than instructions, combined instructions can function like the coach does in cooperative learning situations. Further research is needed.

The current study has practical implications for the design of procedural instructions that will be used for prompted assembly (i.e., when recall of instructions and transfer of learned concepts to similar tasks are not important). If at all possible, procedural instructions should contain illustrations and text. Operational information should appear in at least one of these two formats. When totally written instructions are used instead of combined instructions, then linear step-by-step text is recommended. This text is read and enacted quicker than explanatory procedural information. When totally illustrated instructions are used instead of combined instructions, then a detailed series of subassembly diagrams should be used because a single exploded diagram does not provide sufficient operational information to build accurately and efficiently.

In the current study all measures of comprehension were of equal importance. That is, total session time, planning time, performance time, performance efficiency, and performance accuracy were all important. This is generally not the

case with all assembly tasks. For example, assembly or disassembly of a live bomb requires speed, accuracy and efficiency. Assembly of large objects, such as when someone uses a crane to move the assembly parts, requires accuracy and efficiency. Assembly of small toys requires accuracy.

Designers of instructions should consider the trade-offs in the relative importance of time, efficiency, and accuracy when designing procedural instructions. As the research of Bromage & Mayer (1981), Konoske (1985), and Smith & Goodman (1984), and others suggests, linear step-by-step instructions are insufficient if the purpose is to teach concepts or promote transfer of skills to related tasks. Pedagogical procedural instructions should contain hierarchical, explanatory information.

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FIGURE 1: Minimal Illustration, No Text (Exploded Diagram)

INSTRUCTIONS

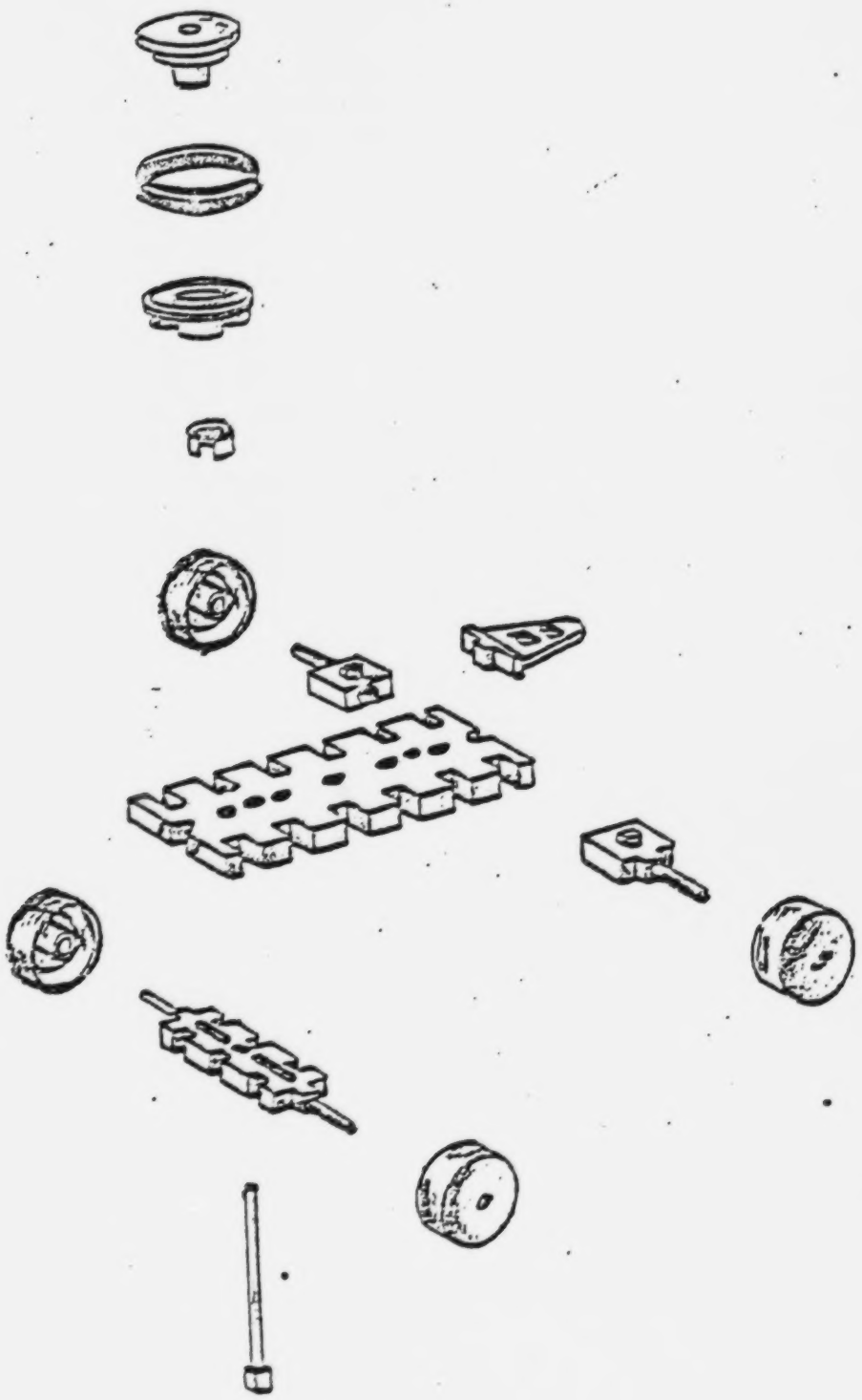

Figure 2: Enhanced Illustration, No Text
(Steering Assembly)

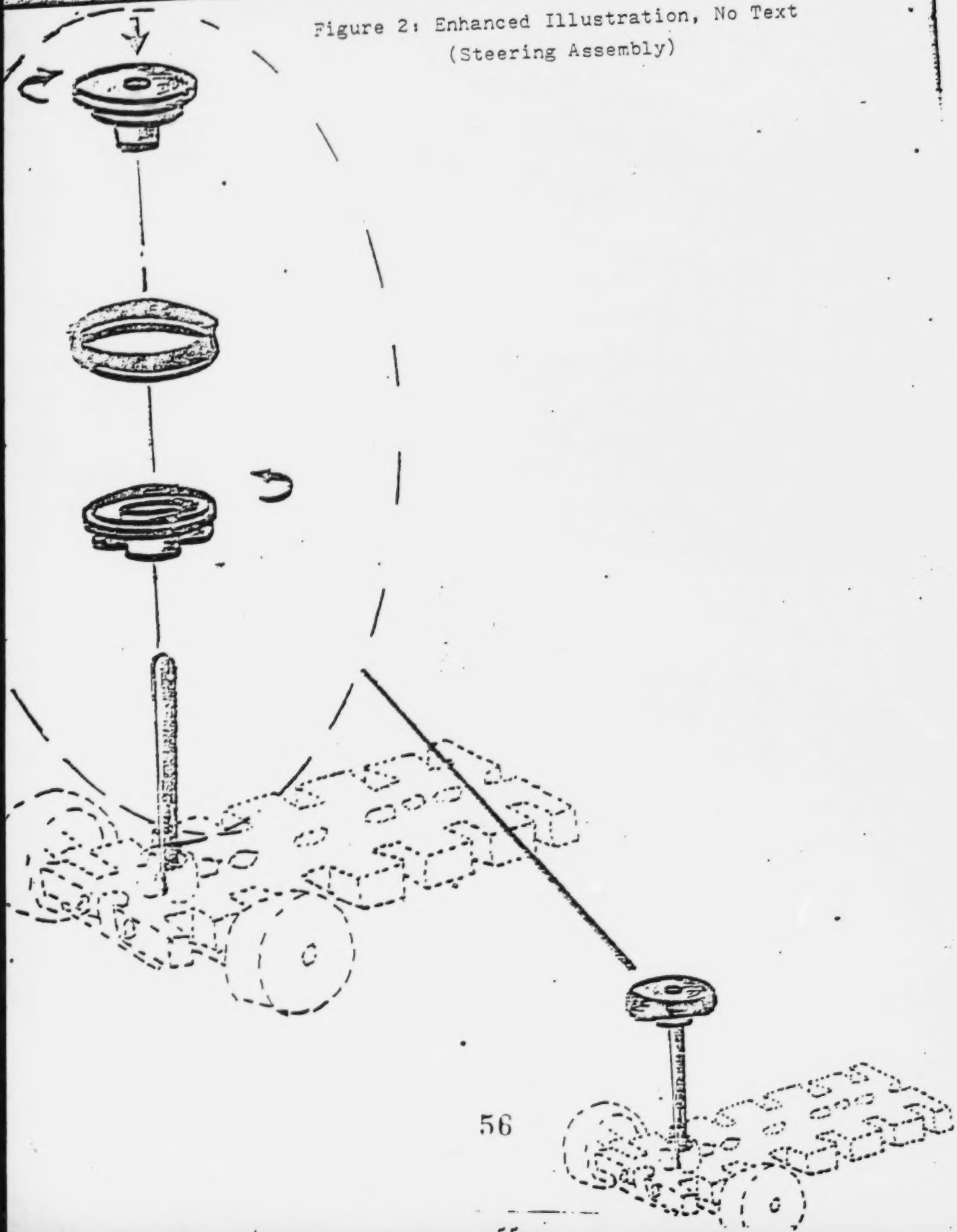

Figure 3: No Illustration, Minimal Text (Linear Text)
Steering Assembly

Hold the steering wheel top in one hand. Use the other hand to put the steering wheel rim around it like a tire on a wheel.

Take the steering wheel bottom and screw it clockwise into the steering wheel top.

Unscrew the steering wheel bottom until the hole is wide enough to fit over the steering column.

Put the steering wheel top, steering wheel rim, and steering wheel bottom at the top of the steering column. Tighten the steering wheel bottom (turn counter-clockwise).

The flat side of the steering wheel top should be at the top of the steering column.

Figure 4: No Illustration, Enhanced Text (Explanatory, Hierarchically Organized)--Steering Assembly

Now begin the steering sub-assembly. The steering sub-assembly has three parts--the steering wheel top, the steering wheel bottom and the steering wheel rim . The steering sub-assembly connects to the front end through the steering column. The steering sub-assembly controls the positioning of the front end when you turn the steering wheel.

To build the steering sub-assembly, hold the steering wheel top in one hand. Use the other hand to put the steering wheel rim around it like a tire on a wheel. Take the steering wheel bottom and screw it clockwise into the steering wheel top. Unscrew the steering wheel bottom until the hole is wide enough to fit over the steering column. Put the steering sub-assembly on the top of the steering column. Tighten the steering wheel bottom (turn counter-clockwise). The <u>flat</u> side of the steering wheel top should be at the <u>top</u> of the steering column.

Table 1

Design for the Study of the Planning Performance Trade-Off in Use of Textual and Illustrated Procedural Instructions [a]

	A. Illustrations 1. None [b, c]	2. Minimal (Exploded Diagram)	3. Enhanced (Series of Diagrams)
B. Text 1. None	[1] No Illust/ No Text	[2] Min Illust/ No Text	[3] Enhanc Illust/ No Text
2. Minimum (Linear)	[4] No Illust/ Min Text	[5] Min Illust/ Min Text	[6] Enhanc Illust/ Min Text
3. Enhanced (Explanatory)	[7] No Illust/ Enhanc Text	[8] Min Illust/ Enhanc Text	[9] Enhanc Illust/ Enhanc Text

Notes: [a] The research design was a series of five omnibus one way analyses of variance (ANOVAs). The three levels within the factors of illustration and text (none, minimal and enhanced) were collapsed for the analyses. All analyses were followed by the Tukey-HSD Multiple Range Test. The dependent measures were: total session time, planning time, performance time, assembly efficiency (number of moves) and assembly accuracy (accuracy score).

[b] Group one was a control. Each group contained 12 subjects (six males and six females). N= 108.

[c] All subjects were give: task goal; the number, name and illustration of the needed parts; method of testing the operation of the assembled go-cart; and, method of informing the experimenter that the subject had completed the task. The nine instructions varied the presentation of "how-to" information within the illustrations and text.

Table 2

Total Session Time Per Group, In Seconds

	A. Illustrations		
	1. None	2. Minimal (Exploded Diagram)	3. Enhanced (Series of Diagrams)
B. Text			
1. None	[1] 937.25 (401.55)	[2] 871.08 (540.04)	[3] 652.42 (246.97)
2. Minimal (Linear)	[4] 930.75 (265.51)	[5] 905.42 (242.76)	[6] 828.08 (281.39)
3. Enhanced (Explanatory)	[7] 1140.25 (409.26)	[8] 859.25 (198.25)	[9] 718.42 (195.02)

Note. Each group had 12 subjects. Average session time for the entire sample was 871.44 seconds (N= 108) with s.d.= 341.75. Parentheses () identify standard deviations.

Table 3

Planning Time Per Group, In Seconds

	A. Illustrations		
	1. None	2. Minimal (Exploded Diagram)	3. Enhanced (Series of Diagrams)
B. Text			
1. None	[1] 235.08 (92.81)	[2] 224.92 (91.34)	[3] 296.33 (95.93)
2. Minimal (Linear)	[4] 528.25 (134.33)	[5] 602.08 (150.23)	[6] 541.17 (188.87)
3. Enhanced (Explanatory)	[7] 707.08 (225.96)	[8] 583.17 (96.76)	[9] 480.33 (152.44)

Note. Each group had 12 subjects. Average planning time for the entire sample was 466.49 seconds (N= 108) with s.d.= 214.67. Parentheses () identify standard deviations.

Table 4

Performance Time Per Group, In Seconds

	A. Illustrations		
	1. None	2. Minimal (Exploded Diagram)	3. Enhanced (Series of Diagrams)
B. Text			
1. None	[1] 702.17 (341.44)	[2] 646.17 (471.67)	[3] 356.08 (177.84)
2. Minimal (Linear)	[4] 402.50 (170.58)	[5] 303.33 (132.24)	[6] 286.92 (144.99)
3. Enhanced (Explanatory)	[7] 433.17 (251.24)	[8] 276.08 (133.92)	[9] 238.08 (82.13)

Note. Each group had 12 subjects. Average performance time for the entire sample was 404.94 seconds (N= 108) with s.d.= 280.32. Parenthese () identify standard deviations.

Table 5

Performance Efficiency Per Group, Measured by Number of Moves

A. Illustrations	1. None	2. Minimal (Exploded Diagram)	3. Enhanced (Series of Diagrams)
B. Text			
1. None	[1] 819.67 (427.42)	[2] 919.58 (721.01)	[3] 445.33 (236.93)
2. Minimal (Linear)	[4] 522.50 (354.18)	[5] 390.33 (360.35)	[6] 309.83 (107.00)
3. Enhanced (Explanatory)	[7] 429.25 (373.07)	[8] 335.42 (229.19)	[9] 271.00 (92.23)

Note. Each group had 12 subjects. Average performance efficiency for the entire sample was 493.66 (N= 108) with s.d.= 415.26. Parentheses () identify standard deviations.

Table 6

Performance Accuracy Per Group, as Measured by Accuracy Score

	A. Illustrations		
B. Text	1. None	2. Minimal (Exploded Diagram)	3. Enhanced (Series of Diagrams)
1.None	[1] 88.25 (6.45)	[2] 89.50 (12.26)	[3] 95.67 (10.79)
2.Minimal (Linear)	[4] 96.75 (3.86)	[5] 96.50 (6.63)	[6] 98.00 (4.84)
3.Enhanced (Explanatory)	[7] 96.00 (6.27)	[8] 96.50 (7.10)	[9] 100.75 (1.54)

Note. Each group had 12 subjects. The average accuracy score for the entire sample was 95.32 (N= 108) with s.d.= 7.98. Parentheses () identify standard deviations. The highest possible accuracy score was 102.

Table 7

Analyses of Variance for Total Session Time, Planning Time, Performance Time, Performance Efficiency and Performance Accuracy

1. Total Session Time

Source	df	SS	MS	F	p value
Between Groups	8	1856132.96	232016.62	2.16	.04*
Within Groups	99	10640423.58	107479.03		
Total	107	12496556.55			

2. Planning Time

Source	df	SS	MS	F	p value
Between Groups	8	2883920.41	360490.05	17.43	.0000***
Within Groups	99	2047072.58	20677.50		
Total	107	4930992.99			

3. Performance Time

Source	df	SS	MS	F	p value
Between Groups	8	2621067.33	327633.42	5.61	.0000***
Within Groups	99	5786956.33	58454.10		
Total	107	8408023.67			

4. Performance Efficiency

Source	df	SS	MS	F	p value
Between Groups	8	4969127.57	621140.95	4.56	.0001***
Within Groups	99	13482194.75	136183.79		
Total	107	18451322.32			

5. Performance Accuracy

Source	df	SS	MS	F	p value
Between Groups	8	1511.24	188.91	3.52	.0013**
Within Groups	99	5310.42	53.64		
Total	107	6821.66			

Note. Each one-way analysis of variance compared nine instructional groups. Three levels within the factors of illustration and text (none, minimal and enhanced) were collapsed.
p< .05* p< .01** p< .001***

Table 8

Summary of Major Findings in the Study of the Planning Performance Trade-Off In Use of Textual and Illustrated Procedural Instructions

Time: The predictions were partially supported. All groups with combined instructions had equal session times.

Enhancements to the text-only instructions extended the total session time; this was attributed to longer planning time.

However, enhancements to illustration-alone instructions shortened the total session time by decreasing the planning time. The group with enhanced instructions and no text performed for an average amount of time, equal to groups given combined instructions.

Groups given instructions that lacked operational information caused them to perform during most of the session.

Efficiency: The predictions were partially supported. All groups with combined instructions made less moves (i.e., were more efficient) than groups given illustrations lacking operational information.

Enhancements to the text-only instructions caused users to make less moves than the group given an illustration lacking operational information.

Enhancements to the illustration-only instructions caused users to make an average number of moves equal to the groups given combined instructions.

Accuracy: The predictions were partially supported. However, accuracy was less affected by the instructions than time and efficiency. It is possible that the information common to all groups provided enough clues to promote a certain level of accuracy.

Enhancements to combined instructions improved accuracy scores as compared to the groups given no instructions or an illustration lacking operational information.

Conclusion: There was a trade-off between combined instructions, on the one hand, and totally written or totally illustrated instructions, on the other hand.

Operational information had to appear in at least one format. Enhancements to text-only and illustration-only instructions affected planning time differently but affected efficiency and accuracy the same.